# TELESCOPE TO EYE ADAPTION FOR MAXIMUM VISION AT DIFFERENT AGES.

The physiological change of the human eye with age is surely contributing to the poorer shooting performance of older shooters. This is regardless of the fact that the refractive deviation of the eyes is generally faithfully corrected with lenses or surgery (laser procedures) and hopefully optometrically restored again to 6/6 effectiveness. Also, blurred eye lenses (cataracts) get replaced in the over sixty group. So, what then is the reason for seeing “poorer” through the telescope after the above?

The table below speaks volumes about this. The iris opening (pupil size) of the eye determines the amount of light (the eye pupil in mm diameter) that enters the eye under specific light conditions. This amount of light, actually photons in the sight spectrum that contains the energy to activate the retina photoreceptors, again determines the clarity of the information / image interpreted by the brain via the retina's interaction. As we grow older, less light is entering the eye because the iris dilator muscle adaptability weakens as well as slows down.

| **Average eye pupil diameter change versus age** | | |
|---|---|---|
| **Age in years** | **Day iris opening in mm** | **Night iris opening in mm** |
| 20 | 4.7 | 8 |
| 30 | 4.3 | 7 |
| 40 | 3.9 | 6 |
| 50 | 3.5 | 5 |
| 60 | 3.1 | 4.1 |
| 70 | 2.7 | 3.2 |
| 80 | 2.3 | 2.5 |

The following calculations, based on the values in the table above, show how drastic these eye pupil changes are on our sight due to the less light that enters the eye. (Keep in mind that a circle's area decreases by the square of the radius reduction.)

The day eye pupil area of a:

- 20-year-old with iris opening of 4.7 mm = $\pi \times (4.7 \text{ mm} / 2)^2 = 17.3 \text{ mm}^2$
- 40-year-old with iris opening of 3.9 mm = $\pi \times (3.9 \text{ mm} / 2)^2 = 11.3 \text{ mm}^2$
- 70-year-old with iris opening of 2.7 mm = $\pi \times (2.7 \text{ mm} / 2)^2 = 5.7 \text{ mm}^2$

A 70-year-old's eye therefore only get about 33% [$(5.7 \text{ mm}^2 \times 100\%) / 17.3 \text{ mm}^2$] of the light or photons of a 20-year-old’s under the same light conditions. That's why we think the "beloved" telescope does not work so nicely anymore, or the lenses on the inside are dirty, our eyes are done, etc. The photon reduction on the retina gives weaker / less clear images and to get clarity back from the weaker image due to the drastic light reduction, the object looked at should be:

- Lightened up in order for it to deliver two to three times more light. (Indoors, for example, the brightness of TV and computer displays can be set higher and reading material brightened with reading lights etc.)
- Optically enlarged by two to three times to view a larger image (though still dull) with more detail of remotely perceived objects. This is the only correction possible for targets / animals as with shooting and hunting.
  (A magnification of say three times let the image through the telescope appear three times closer than with the naked eye.)

If one could see "nicely" in your youth with x 4 magnification, double and more optical magnification would be needed now. Note that the smaller iris openings also have a positive effect on the image by improving the depth of field.

The bundle of light from a telescope (exit pupil) that contains the image information is the diameter of the objective (front) lens divided by the telescopes magnification. The relationship between this exit pupil and the eye pupil is as follows:

a) If the diameter of the light bundle is greater than the eye pupil, some light is lost by not being able to enter the eye but the brightness of the image is still seen as by the naked eye. This is because the same amount of photons enters the eye and is available to the retina.
b) If the diameter of the bundle of light is less than the eye pupil, less light enters the eye than with the naked eye and is therefore observed as duller. The image is also distorted by the outer edges because of a phenomenon called vignetting. (Optically, it is the reduction of the brightness or saturation of the image on the outer edge compared to the image center). This is caused by the darker shadow ring around the lightened spot or area on the retina.

A 4 x 32 telescope gives an exit pupil of 8 mm (32 mm / 4) that will even fill the youngest eye iris opening in the weakest light, with the result that the image is always observed as bright as with the naked eye and without vignetting image distortion, even at night. However, to make up for the 70 year-old's 67% less light intake, enlargement of probably x 10 is required.

For a 32 mm objective lens, it provides an exit pupil of only 3.2 mm (32 mm / 10), which will keep his 2.7 mm day iris opening comfortably filled, also just-just his night eye pupil which is also 3.2 mm, so no problem.

However, if his 30 year old son is using this "combination", it will not work for him. The 3.2 mm light bundle will not fully fill his day iris opening of 4.3 mm and now 55% less light enters the eye which makes the image dull and distorted. This calculation is:

Area of iris opening of 4.3 mm = $\pi \times (4.3 \text{ mm} / 2)^2 = 14.5 \text{ mm}^2$
Area of exit pupil light bundle of 3.2 mm = $\pi \times (3.2 \text{ mm} / 2)^2 = 8 \text{ mm}^2$ and $(8 \text{ mm}^2 \times 100\%) / 14.5 \text{ mm}^2 = 55\%$

He will therefore be able to use maximum x 7.4 (32 mm / 4.3 mm) magnification in the day. If he wants to use x 10, the objective lens must become bigger. It will then be 10 x 4.3 mm giving a 43 mm lens. Should he want to use it at night too, it should be even bigger. Even a 50 mm will not work on x 10 as 50 mm / 7 mm (his night eye pupil) gives a maximum magnification of only 7.1. For x 10 magnification, a 70 mm (10 x 7 mm) lens will be required, which is not practical.

The aforementioned comes down to:

- Younger persons need less enlargement than older persons, for the same image clarity as their eyes let more light in.
- Younger persons need larger objective lenses, thus larger telescopes than older persons, at the same magnification. (To keep the exit pupil big).
- Older persons will not get out of sufficient exit pupil with 36 ~ 44 mm objective lenses and can therefore cope with smaller telescopes.
- Magnification of more than x 7 at night for younger persons without very large (minimum 60 mm) telescopes, is not effective.

[Not all salesmen will necessarily agree with this because the older persons with smaller pupils usually have larger wallets for the purchase of larger telescopes]

The table below shows the maximum optimal magnification for different ages when a 6-24 x 50 telescope is used.

| **Maximum optimal magnification of a 6-24 x 50 telescope, versus age for the average eye** | | |
|---|---|---|
| **Age in years** | **Day enlargement** | **Night enlargement** |
| 20 | 11 | 6 |
| 30 | 12 | 7 |
| 40 | 13 | 8 |
| 50 | 14 | 10 |
| 60 | 16 | 12 |
| 70 | 19 | 16 |
| 80 | 22 | 20 |

From a technical point of view, there is therefore no real use for the full magnification of this telescope.

For hunting over shorter distances in bushy areas, where not only fast aiming and shooting is necessary, but also moving game must be followed, the following also limits the practical magnification regardless of the objective lens size. The bigger the:

- Exit pupil versus the eye pupil, the faster one can aim and shoot. The eye alignment with the ocular (back) lens is then not so critical because the bundle of light is much larger than the eye pupil.
- Field of view, the larger the area that is visible through the telescope and it is inversely proportional to magnification. Typically, the linear area / field at 100 m is about 12 m on x 3 magnification and only 4.5 m on x 9 magnification.

Practically, it means that at a distance of 100 m on x 9 magnification, an animal in sight need only to move 2.25 m to the left or right to be out of the field of vision. At 50 m it will be less than 1.3 m which is completely impractical.

For precision range shooting with time on hand and long distance hunting in open plains, it is of course not so critical.

It should also be noted that larger objective lenses do not in themselves pass more light through in poor light conditions or give a greater field of view.

In summarised thus:

- Younger persons and older persons cannot use the same telescope optimally.
- Hunters in a dynamic environment where rapid aiming and shooting is required and long-range target persons with aiming time available, also not.

Good anti-reflection layers on the lenses, accurate optical settings, high quality components, added crosshair (Mil Dot & MOA) features, parallax adjustment, etc. will of course provide further clarity and benefits, with similar specifications.

As the purpose of this exercise was only to determine the correct exit pupil size and pointing out the disadvantages of excessive magnification under certain conditions, the arguments regarding which magnification are really needed for the distance and target size for which it will be used, are excluded.

Graphic illustration of terminology used: